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## FREQUENCY OF EXCESSIVE RAINFALLS IN FLORIDA

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HYDRAULICS DIVISION

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# FREQUENCY OF EXCESSIVE RAINFALLS IN FLORIDA

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## SYNOPSIS

A study of one aspect of the excessive rainfalls recorded at five locations in Florida is presented herein. This paper illustrates the empirical expressions which relate the intensity and frequency of occurrence of heavy rains of short duration. The method of analysis and the presentation of results follow those established in similar studies from other localities. A comparison is drawn with a study made in 1935. It is seen that only minor changes are necessary in applying the results of this previous work, even though the present study has lengthier records from which to draw.

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## INTRODUCTION

A proper balance between safety and economy in the construction and operation of many differing types of engineering structures depends on a working knowledge of the rainfall characteristics in the areas under consideration. Consequently, an analysis of the interrelations existing between the intensities, durations, and frequencies of excessive rainfalls is a necessary requirement for the engineering design of these structures.

The studies made by D. L. Yarnell, M. ASCE, supplied some of these data for the entire United States.<sup>2</sup> However, the unusual geography of Florida has

<sup>2</sup> "Rainfall Intensity-Frequency Data," by D. L. Yarnell, *Miscellaneous Publications No. 204*, U.S.D.A., Washington, D. C., August, 1935.

created uncertainty as to the propriety of supplying these data to local problems. Much additional basic data have been added to the rainfall records in the period from 1935 to 1951.

The purpose of this study was to analyze rainfall data in Florida in order to determine the frequency with which excessive rates of precipitation occur in various sections of the state. In this study attention was directed to high-intensity rainfalls whose duration was from 5 min. to 100 min.

Investigations of this type require long-time records such as those which are obtained from automatic recording rain gages. There were in 1950 seventy-seven recording rain gages in Florida, of which seventy-one were placed in operation subsequent to 1940. The six remaining stations were established at a significantly earlier date.

For statistical purposes data obtainable from the newer stations will yield results of a lesser order of precision than those data from the older stations. For this reason no station which had records of less than ten years was considered for inclusion in this study. This criterion eliminated all stations but six. Table 1 lists pertinent information relating to the five stations selected

TABLE 1.—RECORD DATA ON FLORIDA RAINFALL STATIONS  
SELECTED FOR STUDY

	First year of record	Last year included	Years of record	Number of storms analyzed
Pensacola	1902	1948	47.5	720
Apalachicola*	1922	1948	24.0	328
Tampa	1905	1948	44.6	751
Miami	1911	1948	38.3	712
Jacksonville	1910	1947	39.0	556

\* Record discontinued from August, 1933, to January, 1937.

for this study. The records of the sixth station (Key West) were not readily available and were not included. The geographical location of the five stations is shown in Fig. 1.

#### RAINFALL RECORDS

The basic data for this study were collected from the individual recording stations. This information included each entry of excessive precipitation in the daily record of the Weather Bureau, United States Department of Commerce (USWB), from the beginning of each record.

During the periods of record the USWB rule for defining and the method of tabulating excessive precipitation were changed. Prior to 1933, Florida storms attaining 1 in. or more, in 1 hr or less, were considered excessive. In 1933, however, the rate which differentiated excessive storms from others was changed to conform with

$$y_a = 2 t_m + 30 \dots \dots \dots (1)$$

in which  $y_a$  is the accumulated depth in hundredths of an inch, and  $t_m$  is the time in minutes.

In 1936 the method of tabulating excessive precipitation was also changed. The method previously used gave the accumulated depth of precipitation for each 5 min. during a storm. The tabulation began with the first 5-min. period in which at least 0.05 in. of rain were measured, after which the tabulation was continued for each succeeding 5-min period. The method established in 1936 furnishes a record of the maximum rainfall occurring during the storm for each time interval. The record shows the maximum amounts for 5 min, 10 min, 15 min, 20 min, 30 min, 45 min, 60 min, 80 min, 100 min, 120 min, 150 min, and 180 min.

Although this latter method tended to increase the amounts of rainfall measured during the various time increments, no distinction was made in the analysis of the two types of data. Also, the change made in the 1933 definition of excessive rainfalls tended to decrease the number of storms so recorded. This analysis, however, is not affected since the rates of rainfall which did not equal or exceed those indicated by Eq. 1 were discarded from the grouped data.

There are also certain inherent deficiencies in rainfall data of the type used. These factors have been investigated by A. J. Schafmayer, M. ASCE, and B. E. Grant,<sup>3</sup> and others.<sup>4</sup> However, most errors of this nature are minimized when

<sup>3</sup> "Rainfall Intensities and Frequencies," by A. J. Schafmayer and B. E. Grant, *Transactions, ASCE*, Vol. 103, 1938, p. 344.

<sup>4</sup> "Hydrology Handbook," ASCE *Manual of Engineering Practice No. 28*, 1949, p. 9.

long-time records such as those in this study are used.

TABLE 2.—NUMBER OF OCCASIONS WHEN THE AVERAGE INTENSITY OF RAINFALL REACHED OR EXCEEDED THE INDICATED INTENSITY FOR THE INDICATED DURATION AT FIVE CITIES IN FLORIDA

Duration of Storm, in Minutes	AVERAGE INTENSITY, IN INCHES PER HOUR											
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0 and over
PENSACOLA												
5				324	201	116	76	94	59	43	22	16
10				205	109	63	35	44	22	14	7	4
15			342	136	69	40	26	20	11	5	3	2
20		381	247	57	32	17	8	14	8	3	3	3
30		216	123	21	11	6	1	2	2	1	1	1
45		103	52	12	8	2	1	1				
60	131	54	23	10	4							
80	72	30	15									
100	43	18	11	7								
APALACHICOLA												
5				138	86	49	27	42	28	20	7	3
10				87	45	22	10	18	9	3	2	2
15			144	62	26	13	8	5	3	1		
20		168	106	24	9	4	1	4	2			
30		96	49	10	2							
45		42	20	1	1							
60	61	25	10									
80	36	12	4	1								
100	17	4	1									
TAMPA												
5				324	191	130	80	87	59	36	22	13
10				185	113	71	39	47	30	14	3	2
15			344	155	63	42	23	23	12	4	2	1
20		383	252	71	33	20	9	15	7	2	1	
30		218	133	41	22	13	7	4	2			
45		101	41	9	6	3						
60	120	47	19	6	4							
80	59	20	10									
100	22	8	4	1								
MIAMI												
5				300	178	103	61	77	47	28	12	7
10				185	113	56	28	30	18	7	4	2
15			305	133	69	34	16	16	6	5	2	1
20		348	228	62	34	11	5	7	4	2	1	
30		193	112	23	7	4	3	3	2	2		
45		101	52	9	5	2	1	1	2			
60	111	60	27	4	1							
80	79	35	12									
100	46	21	8	1								
JACKSONVILLE												
5				231	153	94	59	88	54	32	17	8
10				161	101	58	33	33	20	9	3	3
15			256	109	60	27	17	19	6	6	1	
20		280	178	60	24	14	5	10	3	3		
30		154	86	46	8	2		3	1	2		
45		63	32	16	1							
60	58	27	12	6								
80	35	12	5									
100	20	7	2									

# ANALYSIS OF DATA

The method of analysis of the data followed conventional practice in the conversion of depths of rainfall into average rates.<sup>5</sup> These rates were grouped

<sup>5</sup> "Hydrology Handbook," ASCE Manual of Engineering Practice No. 28, 1949, p. 16.

for each station to show the number of occasions when the average intensity of rainfall reached or exceeded an indicated intensity for an indicated duration. These complications are given in Table 2. Interpolation into Table 2 yields the various durations of rainfall intensities which occurred once in 0.25 yr, 0.5 yr, 1 yr, 2 yr, 3 yr, 4 yr, and 6 yr at each station.

In empirical curve fitting, it was found that a two-parameter, reciprocal equation of the generalized form,

$$i = \frac{d}{j + t_a} \dots \dots \dots (2)$$

proved most adaptable for expressing the intensity-duration relationship found for each of the seven frequencies investigated. In Eq. 2,  $i$  is the average rainfall intensity in inches per hour,  $t_a$  denotes time in minutes over which the average intensity occurs, and  $d$  and  $j$  are constants for a given locality and frequency.

When Eq. 2 is converted to

$$\frac{1}{i} = Y + M t_a \dots \dots \dots (3)$$

it becomes a straight-line relation in which  $Y$  indicates the intercept value, and  $M$  is the value of the slope of the line. Fig. 2 shows the high degree of correlation obtained by the use of Eq. 3.

An investigation of each set of data by the method of least squares produced the corresponding values of  $Y$  and  $M$ . In each of the thirty-five cases the coefficient of correlation was greater than 0.99.

Further examination revealed that the values of  $Y$  and  $M$  exhibit a logarithmic trend when compared with the average time intervals between occurrences. Fig. 3 illustrates these relations at Pensacola, Fla. Application of the method of least squares produces the lines of best fit, the equations of which relate the values of  $Y$  and  $M$  to a unit of frequency,  $F$ , expressed as an average frequency of occurrence of once in the indicated number of years. In the  $Y$ -relationships the coefficient of correlation of the data was found to be less than -0.88 in each instance, and in the  $M$ -relationships the coefficient was less than -0.99.

Substitution of the functions obtained by this procedure into Eq. 3 gave a generalized duration-intensity-frequency relationship for each of the five rainfall stations. The resulting equations are, for Pensacola,

$$i = \frac{278}{42.2 F^{-0.12} + t_a (F^{-0.56} + 0.45)} \dots \dots \dots (4a)$$

for Apalachicola, Fla.,

$$i = \frac{400}{63.2 F^{-0.12} + t_a (F^{-0.77} + 1.20)} \dots \dots \dots (4b)$$

for Tampa, Fla.,

$$i = \frac{202}{28.4 F^{-0.10} + t_a (F^{-0.42} + 0.16)} \dots \dots \dots (4c)$$

for Miami, Fla.,

$$i = \frac{370}{60.0 F^{-0.11} + t_a (F^{-0.67} + 0.73)} \dots \dots \dots (4d)$$

and for Jacksonville, Fla.,

$$i = \frac{204}{25.1 F^{-0.04} + t_a (F^{-0.57} + 0.41)} \dots \dots \dots (4e)$$

It can be seen that selection of a numerical value for  $F$  will reduce Eqs. 4 to a specific duration-intensity relationship of the form given by Eq. 2.

#### COMPARISON OF RESULTS

For rainfall durations of between 5 min and 100 min, Eqs. 4 furnish reliable information as to the average rainfall intensities which occur with an average frequency of once in 3 mo. to once in 6 yr. For less frequent occurrences, however, the precision with which an average rate of rainfall can be predicted also decreases. It was felt that a comparison of rarely observed rainfalls with the equivalent computed values would serve to demonstrate the range of reliability of the generalized equations. For this purpose a frequency of once in the period of years of record was selected at each station. The results are presented in Fig. 4 in which the dashed curve represents the computed data. The straight lines connect points of the maximum observed intensities on record.

It is noteworthy that (except at Tampa) the observed and computed values are in excellent agreement. The observed intensities of short duration tend to exceed the computed ones, but for longer durations these differences become relatively small. In general, then, it can be stated that the relations expressed for the various rainfall stations will permit extrapolation for frequencies less than those used in the derivations (less than once in 6 yr).

A comparison of the results of this study with those of Mr. Yarnell<sup>2</sup> furnishes additional insight into the consistency of rainfall frequencies in Florida. Table 3 has been prepared for this purpose. Average intensities for durations of 5 min, 15 min, 30 min, and 60 min were obtained by interpolation of Mr. Yarnell's charts which showed the rainfalls to be expected on an average of once in 2 yr, 5 yr, 10 yr, and 25 yr. The corresponding intensities were computed by use of Eqs. 4. The values in Table 3 represent the deviation of Mr. Yarnell's results

TABLE 3.—PERCENT DEVIATION OF D. L. YARNELL'S RESULTS FROM PRESENT ANALYSIS FOR FIVE CITIES IN FLORIDA

Duration, in minutes	Pensacola	Apalachicola	Tampa	Miami	Jacksonville
5	4	11	1	11	1
15	-6	5	-4	2	-2
30	-12	3	-6	-2	-6
60	-18	-1	-11	-10	-7

from those of this analysis. Each value is an average of the percentage variations found for the four frequencies listed.

At the five stations examined a small but significant trend is in evidence. The records which have been added since the study made in 1935 show that for short durations the earlier study indicated intensities which were too large, but for longer durations the intensities appear to be somewhat less than this study demonstrates. No doubt these differences are caused by the change in the method of tabulation. The variations are not great, however, and it can be concluded that the rainfall characteristics at the five stations studied have not varied to any appreciable degree during the period of records.

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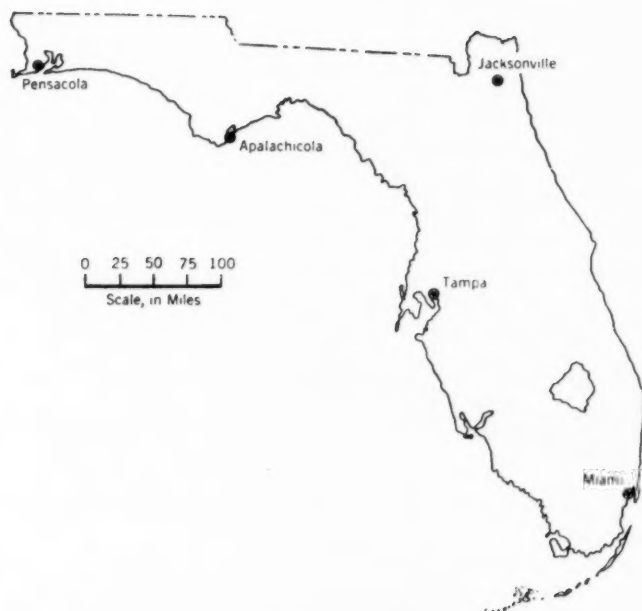


FIG. 1.—LOCATION OF FIVE RAINFALL STATIONS IN FLORIDA

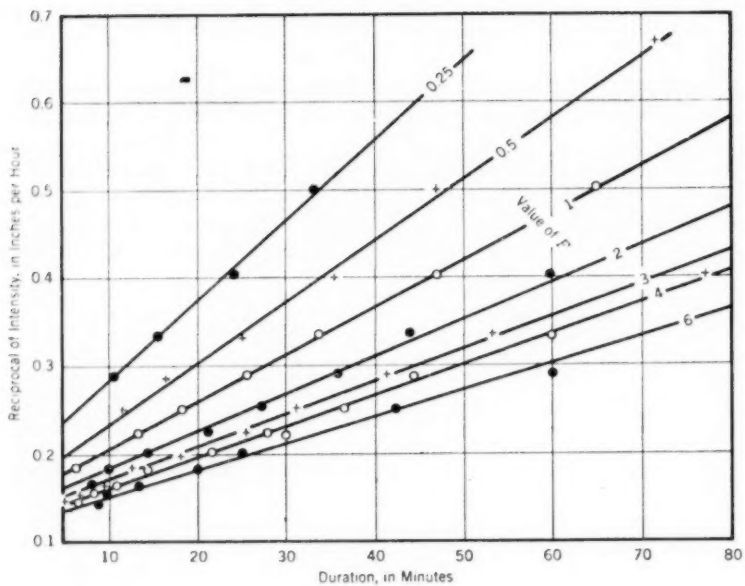


FIG. 2.—DURATION-INTENSITY RELATIONSHIPS FOR VARIOUS FREQUENCIES AT PENSACOLA, FLA.

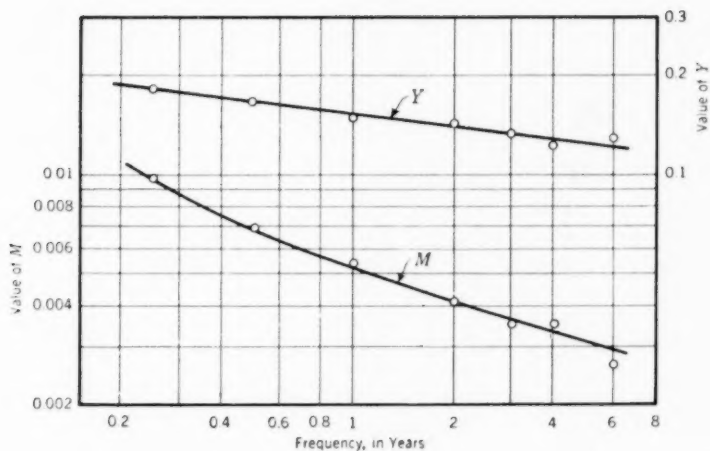


FIG. 3.—RELATIONSHIP BETWEEN FREQUENCY AND VALUES OF  $Y$  AND  $M$  AT PENSACOLA, FLA.

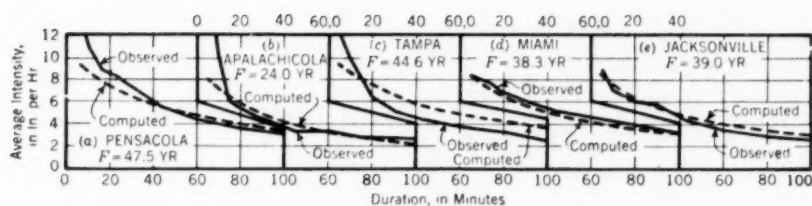


FIG. 4.—COMPARISON BETWEEN OBSERVED AND COMPUTED RAINFALLS FOR THE INDICATED FREQUENCIES FOR FIVE CITIES IN FLORIDA

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